SHOP FOR MACHINING BERYLLIUM is part of Oak Ridge Y-12 plant operated by Carbide and Carbon Chemicals Company for the U S Atomic Energy Commission. Because of health hazards associated with beryllium, shop contains many unusual features to prevent exposure of personnel. Spotless condition of walls, floors, ceilings, and other surfaces is maintained at all times. Broom is never used but two men spend their full time washing, mopping and scrubbing shop. Machines are hooded and air is monitored and controlled

HOW OAK RIDGE *machines beryllium*

Finish machining of beryllium has been performed on a large scale in a shop specially planned for this purpose at Oak Ridge. Here's the story of the unusual precautions taken to protect workers from this material, together with the latest data on deep-hole drilling, milling, and other machining operations

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THE inhalation of beryllium or beryllium compounds as vapors, dust, or mist may cause either acute or delayed chemical pneumonitis. In addition, skin irritation and ulceration observed in cases of beryllium exposure are thought to be caused by beryllium or its compounds penetrating breaks in the skin. The most serious hazard associated with the handling of beryllium, however is the pathology within the lungs. At the present time there is no known form in which beryllium can be taken into the body without causing this effect. There also is apparently no definite correlation between the length and degree of exposure and the occurrence of complications resulting from exposure. Because of these hazards, it obviously is necessaary to prevent the exposure of personnel to beryllium in any form.

At the Oak Ridge Y-12 plant, operated by Carbide and Carbon Chemicals Company, it became necessary to finish machine beryllium parts on a large scale as a part of work on special projects for the Atomic Energy Commission. Because of the size of the project and the health hazards involved, it was decided to renovate an idle experimental machine shop that could be devoted solely to beryllium work.

The entire machining area was first enclosed with wall board, thus isolating the area of greatest dust hazard for monitoring and control. Rafters and rough walls upon which dust could accumulate were kept to a minimum and walls and ceilings were painted to reduce dust coatings. Good housekeeping was, of course, one of the more important safety procedures. To facilitate cleaning, a good coat of glossy paint was painted on floors and machines.

SAFETY PROCEDURES

The shop building also housed an office, a receiving and storage area, a tool-grinding shop, and a locker room and change area. These facilities made it possible for personnel to remain in the building for the entire work shift and helped to prevent random scattering of beryllium dust to uncontrolled areas.

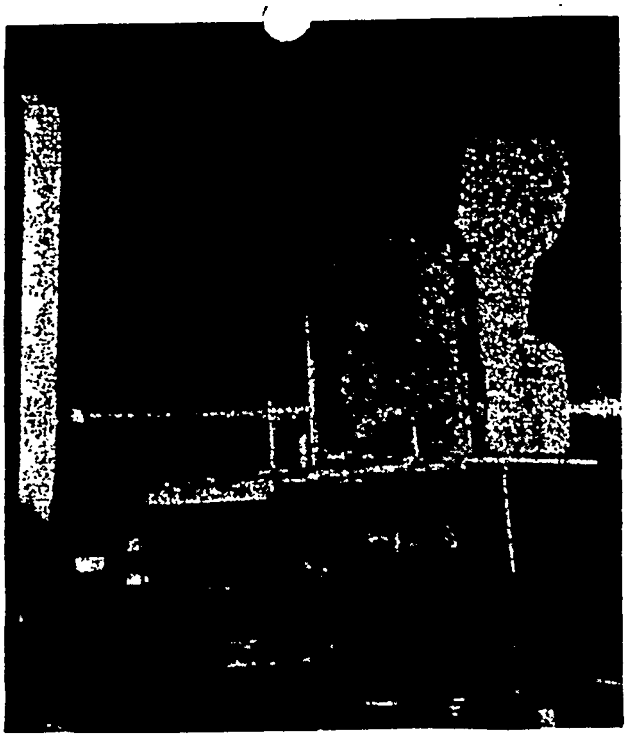
To protect personnel on the job and to confine dust hazards to the shop, the following precautionary measures were rigidly applied:

1. Shop personnel wore protective clothing consisting of underclothing, socks, shoes, white trousers and shirts, caps, and safety glasses.
2. They were permitted to enter and leave the work area only through the locker room.
3. Personal belonging, such as watches, rings, and billfolds were left in the locker room.
4. Smoking and eating were permitted only in designated areas. Each employee was required to wash his hands and put on a laboratory coat when leaving the work area to enter the smoking and eating areas or the rest rooms.
5. Exit from the work area was through the contaminated-clothing area where, at the end of each shift, employees deposited their protective clothing.
6. Clothing was dampened and taken to the recovery laundry.
7. Employees were required to shower before putting on personal clothing; the shower room was located between the contaminated-clothing area and the locker room.
8. Maintenance personnel entering the shop were required to wear protective clothing as prescribed by the shop foreman.
9. Visitors were required to wear shoe covers and lab coats and to sign a register listing name and badge number, and stating time of entry and departure.
10. Vital-capacity tests and weight checks were made bi-weekly on all employees.
11. Chest X-rays and physical examinations were given every three months.

DUST CONTROL

The problem of controlling and disposing of beryllium dust was given concentrated attention. A ventilating system was designed to provide each machine with an exhaust of about 550 cfm through a 5-in flexible hose connected to hoods which enclosed each machining operation.

The principle of the hoods was to create a rapid flow of air from the room over the work surface sweeping all dust directly into the exhaust system.



MILLING-MACHINE HOOD is supported on overarm so bottom of hood is about ½ in. above work. About 550 cfm exhausts through 5-in. flexible hose attached to side of hood. This rapid flow of air from room over work and into hose sweeps all dust into exhaust system, thus holding beryllium concentration in room air well within safe working limits for all operators

To achieve maximum facial velocity, hoods were made as small as the operation would permit. Hoods were constructed from ¼- or ⅜-in. clear plastic sheet, cemented together with ethylene dichloride. Generally, hoods were box-shaped and covered only the point of operation. Various types are shown in the accompanying illustrations.[1]

Initially, for deep-hole drilling, a hood was designed to extend from the headstock to the tailstock of the machine. Its use was discontinued, however, because it carried off large amounts of coolant. As deep-hole drilling was a wet operation, performed inside the piece, the danger of beryllium dust becoming airborne existed only in machining the starting hole. A hood covering only the starting operation was successfully substituted for the large hood.

AIR MONITORING

After installation, the effectiveness of each hood was checked with a portable air sampler. Subsequent spot checks also were made. In addition, continuous air samplers were placed at breathing levels throughout the shop. At no time was the dust content allowed to exceed 2 micrograms per cubic meter.

Air samples were taken by an instrument incorporating a 1.3 cfm air pump and a specially designed sample head clamped to a 45° boom. Air flow was calibrated by a rotameter whose range was 0.02 to

1. For additional information on hoods, see "Hooded Machines Run Toxic and Radioactive Jobs", *AM*—Feb 19 '51, p 133.

BORING OPERATION on large beryllium block is performed in special setup. Boring bar revolves, driven by chuck, while work is mounted on carriage and feed past tool. Vapors, dust, and tiny particles are exhausted by hose. Chips and cutting fluid are held by temporary dam on plate bridging ways. With these measures, enclosure is not required on this operation

SPECIAL WORKHOLDER cuts time for machining convex surfaces on beryllium pieces. Holder supports four pieces, locating them equidistant from centerline. Radius on pieces is slightly more than 5.5 in.

0.08 cubic meters per minute, approximately the normal breathing rate of a working man. A filter paper was selected for use in all sampling devices where sufficient vacuum was available. Determinations of the beryllium content on filters were made by optical spectrographic methods. These are sensitive, rapid, and reasonably reproducible.

As it was considered impractical to monitor simultaneously each of several operations, samplers were located to provide a good general picture of airborne beryllium concentrations in the shop.

In all, twelve permanent air samplers were installed, one in the locker room, seven in the machining area, one in the room housing workpieces, one in the tool-grinding area, and two in the filter house on the influent and effluent sides of the finishing filter. This arrangement provided entirely satisfactory air monitoring of the general shop area throughout the course of the beryllium machining operations.

As an added precaution, permanent air samplers to determine the amount of dust escaping from the exhaust and filter system were placed outside the building in locations selected after a study of local meteorological conditions. The shop was shut down twice during the early stages of operation when dust in excess of the off-plant air pollution limit of 0.01 micrograms per cubic meter was detected escaping from the exhaust tank. These leaks were sealed, and no further difficulty was encountered.

The material ordinarily processed was hot-pressed QMV beryllium. Castings were received rough machined with approximately ⅛-in. excess stock on plane surfaces. Operations included surfacing, grooving, deep-hole drilling, facing, and boring.

DEEP-HOLE DRILLING SETUPS

Deep-hole drilling had been considered one of the major beryllium fabricating problems. During the course of machining operations covered by this article, 15,724.75 in. of 3/16 and ¼-in. holes, ranging from 8.50 to 39.50 in. in length, were drilled in various beryllium parts. The experimental stage in deep-hole drilling was conducted during the machining of 3/16-in. axial holes and the procedure finally developed is illustrated by this operation.

The work was rotated in a deep-hole drilling machine at 1500 rpm, and a stationary 3/16-in. tungsten carbide-tipped drill was fed into the beryllium at 0.0004 inch ipr. The coolant pressure was 200 psi.

Three drills stepped at lengths of 27, 42, and 57 in. were used successively to drill the length of the piece and a guide bushing was employed with each drill. With this technique, runout was held within 1/64-in. for a 3/16-in. hole 39.5 in. deep.

All parts of small cross-section was drilled on the deep-hole drilling machine. Pieces that could not be rotated were drilled on a lathe. The work was mounted on the carriage and the drill was rotated. Machine speed was 1500 rpm, and the feed was from ¾ to 1 ipm.

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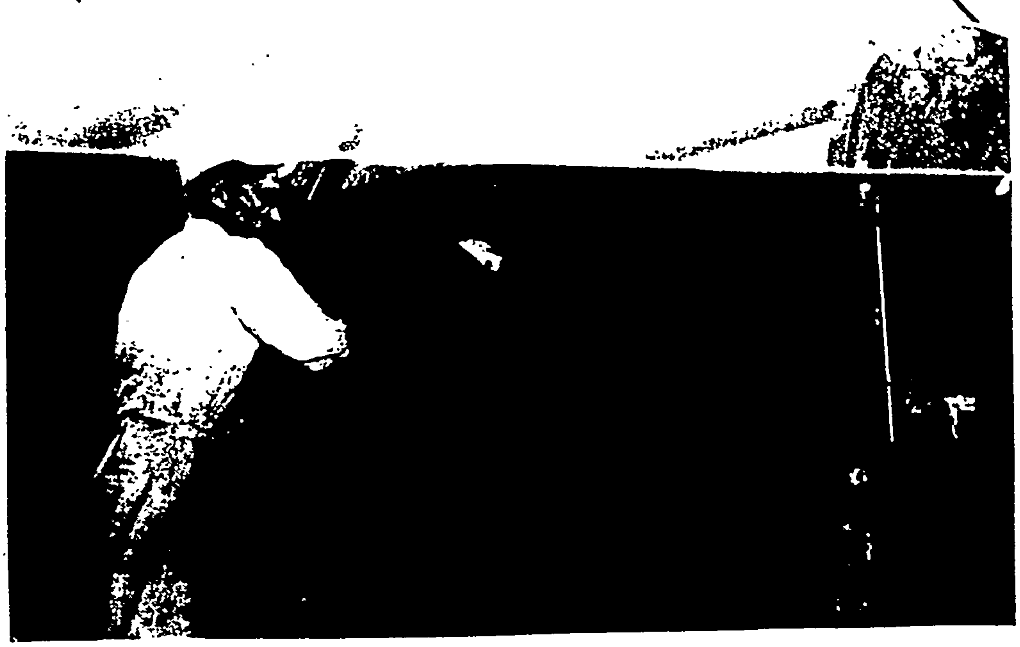


SAFETY GARB worn by all workers in the beryllium room includes white uniform that is changed and laundered daily, safety shoes that are never removed from the shop, safety goggles, and gloves. Showers are required at end of each working day. Operator is handling beryllium with rubber gloves similar to those turned inside out at right

During initial operations on the deep-hole drilling machine two drill shanks were broken off in the work. This breakage was attributed to the coolant. To permit experimentation with the coolant without risking tool breakage, a special toolholder was devised that would automatically disengage the drill from the drive when the load became excessive.

In this design, the drill was placed in a revolving socket in the toolholder. The collar of the socket was provided with a single cam which rested on a lever attached to the face of the toolholder. This lever was held by a spring adjustment at a tension sufficient to hold the drill in place against normal machining pressure. If the pressure became excessive. the cam would trip the spring lever and permit the drill socket to rotate in the toolholder. This attachment was used throughout the deep-hole drilling operations and effectively prevented drill breakage.

Turpentine was used as the coolant in the first deep-hole drilling operations. Unsatisfactory results were obtained, however, because of its non-lubricating nature. A colloidal dispersion of graphite in mineral oil then was added to the turpentine to provide lubrication. This mixture was used successfully until turpentine was received with odor so objectionable that it could not be used.

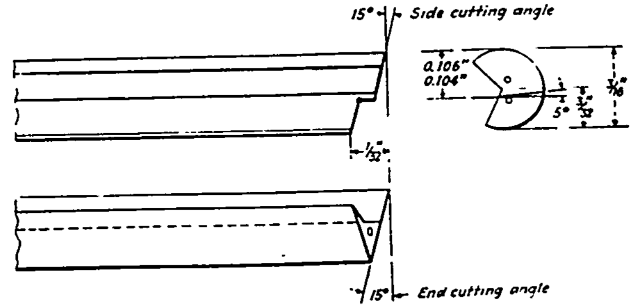
To avoid waiting for another supply of turpentine. the mixture was replaced by kerosene which gave the desired coolant action, was cleaner than the turpentine mixture, and had no objectionable odor. On the basis of this experience, kerosene is believed to be entirely satisfactory as a coolant for deep-hole drilling in beryllium.

CARBIDE-TIPPED RIFLE DRILLS

Single-flute, tungsten carbide-tipped rifle drills for deep-hole drilling were purchased. The drill shank was a seamless-steel tube having a diameter slightly smaller than the tip. One side of the shank was depressed to form a "V" groove which extended along its entire length and was continued to the point of operation by the removal of about a third of the cross-sectional area of the tip. Two 1/32-in. coolant holes through the tip, one below each outer corner of the "V" groove, provided for the outlet of the coolant from the hollow shank into the cutting edges. The "V" groove provided for return flow of the chip-laden coolant from the point of operation.

On deep-hole drills the cylindrical peripheral elements of the tool body behind the cutting tip rested on the finished surface of the hole to guide the point into the work. Longitudinal clearance was ground along the tool body to reduce friction and allow coolant flow around the tip and into the "V" groove. On the 3/16-in. drills, the guiding elements of the tip were a cylindrical land 1/64-in. wide below the cutting edge and a bearing surface 7/32-in. wide diametrically opposite the land.

The point of the drill was specially ground for ap-



GUN DRILL FOR BERYLLIUM has tungsten-carbide tip and shank of seamless steel tube. Drill has special grind and "V" groove for chip and coolant removal. Step aids flushing chips from point plication to beryllium work. One cutting edge of the drill was located on one outside corner of the "V" groove, while the other was formed by the adjacent edge of the "V" groove along the face of the tool extending to the center of the drill.

DRILL GRINDING ANGLES

The face of the tool was ground so a line along the cutting edge on the "V" groove made 15° angle with the cross-section of the drill, and any line on the face perpendicular to the cutting edge would intersect a plane perpendicular to the axis of the drill on a 15° angle. Thus, the face receded from the point and the cutting edge of the drill on a compound angle which formed a 15° side-cutting angle and a 15° end-cutting angle. A slight clearance was ground on the point to prevent shearing as it entered the work.

Coolant flow was inhibited initially by the flat surfaces surrounding the coolant holes. To allow a larger space for flushing chips from the point of operation, a second surface was ground around the coolant hole on the lower side of the drill face. This surface was bounded by a line passing between the coolant holes slightly off center, the lower edge of the "V" groove, and the periphery of the drill.

Drills were sharpened on a cutter grinder equipped with a flat diamond abrasive wheel. To insure a true, clean cut and prevent wearing on the cutting edges, which would necessitate complete regrinding, drills were touched up after finishing each hole.

SURFACING AND GROOVING

When surfacing was required on the sides, ends and edges of parts, the sides were machined on a vertical mill and the ends and edges were machined on a horizontal mill equipped with a vertical head. In all surfacing operations, ½-in. square-shank tungsten-carbide-tipped fly cutters were used. The tool had the following characteristics: back rake, neutral; side rake, 8°; side-cutting angle, 7°; side-relief angle, 10°; and nose radius, 1/16-in. This tool was mounted in 3 to 6-in. toolholders, depending on the operation to be performed. For most of the surface operations, a speed of 500 rpm and a feed of 2 ipm for roughing and ¾ ipm for finishing were satisfactory.

Grooves on outside surfaces were machined on a horizontal mill. Tungsten-carbide-tipped fly cutters, having the same cross-section and tool angles as cutters used for surfacing, were employed in the grooving operation. When grooves were 3/16-in. wide, the nose radius on the tool was 3/32-in. and the cutter swing was 6 in. in dia. Again, the speed of the mill was 500 rpm with a feed of 1-½ ipm. To prevent chipping at the end of the groove, the feed rate in all cases was slowed to ¾ ipm over the last inch of cut.

In view of the many similar milling operations encountered, standardization of the cutters and toolholders seemed advantageous. All cutters were ordered having a ½-in. cross-section and standard tool angles. Toolholders for the cutters also were standardized to take ½-in. bits so the need for fitting cutter toolholder was eliminated. As all toolholders were the same size and cutters were interchangeable, each cutter was used for its full cutting life. This standardization permitted savings in both labor and tool costs. Throughout the operation, it was the responsibility of one man to keep a supply of sharpened tools on hand so no delays for tool sharpening were encountered. This reduced machine downtime and tied in nicely with the standardization program.

BORING TECHNIQUES

Some parts required a semicircular cut in one end which, when fitted with its corresponding piece, formed a cylindrical hole 6.750 in. in dia. As this operation was performed on a lathe, it was possible to match pieces of similar cross-section and place them end-to-end so the cut could be made in two pieces simultaneously with a boring technique.

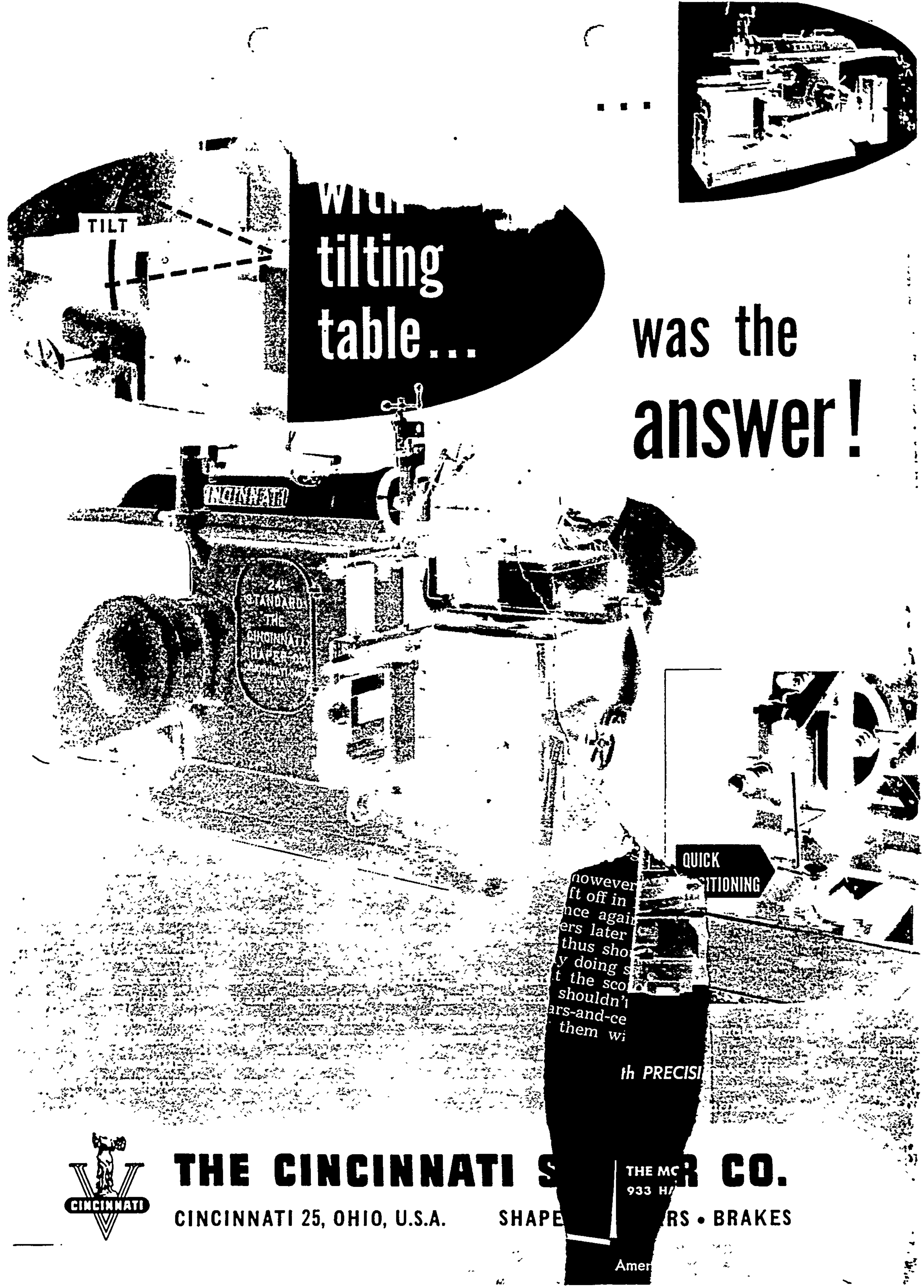
In ordinary drilling and boring operations, a work hole about ¾-in. deep was machined with a 1½ in. counterbore at 68 rpm and 0.0027 ipr. Through the center of the work hole a ¾-in. lead hole was drilled at 129 rpm and 0.0027 ipr. A 2 7/16 in. drill-through at 80 rpm and 0.0027 ipr completed the drilling. All drills were HSS with clearance angles between 57 and 59°.

Rough boring was performed with 2¼ in. and 3 in. boring bars having adjustable bits. Speed was 80 rpm and a feed 0.010 ipr. Rough cuts were continued until the hole was 6 in. in dia. The hole then was finished to 6.750 in. taking successively lighter cuts. In cleanup operations, a speed of 68 rpm and a feed of 0.0052 ipr were used, except for the final cut in which the speed was slowed to 48 rpm. Three-eighths inch tungsten-carbide-tipped tool bits were used in the boring bars. The coolant was a mixture of one part colloidal graphite dispersion to five parts turpentine.

SPECIAL WORKHOLDER

For machining of convex surfaces, considerable time was saved by the use of special workholder. This was spool-shaped, and had fixtures for attaching beryllium pieces at four equidistant locations on its circumference. The radius from the center of the holder to the center of the work was a little greater than 5.5 in. The cutter was a ½-in. tungsten carbide-tipped bit having a neutral rake angle and a 7° clearance angle. On roughing cuts, speed was 216 rpm and feed 4.5 ipm; finish cuts were taken at 129 rpm and 3.2 ipm.

During the machining period covered by this article, 134 pieces of beryllium having a finished weight of about 4,750 lb were machined without spoilage. In the early stages of the work some time was spent in experimentation with hood design, deep-hole drilling, and general machining procedures. The improved efficiency obtained as a result of this experimentation more than compensated for the time invested.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